Met.O.893
METEOROLOGICAL OFFICE

the meteorological magazine

NOVEMBER 1976 No 1252 Vol 105
Her Majesty's Stationery Office

METEOROLOGICAL OFFICE Met.O.893

THE METEOROLOGICAL MAGAZINE

Vol. 105, No. 1252, November 1976

551.521.1:551.521.31

VARIATIONS IN GLOBAL SOLAR RADIATION AT KEW

By J. P. COWLEY

SUMMARY

Global solar radiation data recorded at Kew since 1951 were used to establish changes in the global irradiance at the earth's surface in the absence of clouds. To do this, a characteristic value, the Global Solar Radiation Index, was obtained for each month; the series of values forms a consistent set and the use of such an index is thus justified. Numerical filtering techniques were used to establish seasonal and secular trends in the data. It is suggested that changes found in the winter months are associated primarily with changes in fuel technology, supported by legislation controlling the emission of pollutants into the atmosphere. Variations in the summer months were much less; they form the basis of a separate study

INTRODUCTION

Interest is currently being expressed in changes in the climate of the British Isles. Solar radiation records do not go back far enough for climatic trends in solar radiation to be postulated directly from data. There is, however, a record of hourly average values of the intensity of global solar radiation in the wavelength band of 0·3 to 3·0 micrometres measured at Kew (51° 28′N, 0° 19′W) near London, which began in January 1947, but was of questionable quality before 1951.

An investigation was mounted to establish any trends in global solar radiation at Kew under clear skies since 1951. Any such trends would result from changes in the emphasis to be given to the mechanisms by which solar radiation is scattered and absorbed in passing through the earth's atmosphere. Scattering may be by gaseous molecules (Rayleigh scattering) or by aerosols (Mie scattering). Molecular absorption of solar radiation takes place for certain well-defined frequencies, corresponding to permitted energy transitions within the molecules; atmospheric ozone absorbs the majority of solar ultra-violet radiation incident on the atmosphere, for instance. Atmospheric aerosols also absorb solar radiation, but in a less well-defined manner. The solar radiation reaching the earth's surface would be expected to change significantly both with aerosol content, which may be a function of wind direction, and with the atmospheric water vapour content.

Evans (1957), Brazell (1964), Wiggett (1964) and Jenkins (1969) discuss the decrease in fog occurrences in the London area (and the increase in the duration of bright sunshine) and associate this with the decrease in air pollution. Improvements in the efficiency of fuel burning and change of fuel types, together with successive legislative enactments in 1954, 1956, 1968 and 1971 to restrict the emission of smoke, and later sulphur, from buildings of all kinds, might be expected to result in increases in the measured solar radiation at Kew over this period.

A parameter, the Global Solar Radiation Index, referred to later as the GSRI, was introduced in this work to characterize the global solar radiation that would be expected during any one hour in which the sky was entirely clear.

The sequence of GSRIs was examined for the period from 1951 to 1974 for correlation from month to month and from year to year. Results indicated that a systematic pattern was present together with some fluctuations. It was possible to use the time-series of these indices, by applying low-pass filtering techniques, to demonstrate the trend in GSRI at Kew.

A change in GSRI might be attributed to a number of causes, including

(i) variation in atmospheric scattering or absorbing processes,

(ii) variation in the solar radiation in the wavelength range 0·3–3·0 micrometres incident on the atmosphere, and

(iii) variation in instrument response, or in the reference standard etc.

Careful attention has been paid to the standardization of radiation measurements made at Meteorological Office stations. It is claimed that individual measurements of global solar radiation are subject to two main errors: a zero-shift of less than ± 5 W/m^2 and an instrument calibration error that is less than ± 5 per cent of the value indicated. No significant changes in reference standards have been found at international pyrheliometric comparison meetings. Consequently, it is suggested that (iii) has not been a significant factor in the results obtained.

No evidence is offered to suggest that there have been changes in the solar constant (cf. (ii)). The inference here is that the significant changes found over the period from 1951 onwards are to be associated with changes in levels of atmospheric pollution and the attendant scattering processes.

Measurements

Two types of measurement were used in this study: hourly averaged global solar irradiance on a horizontal surface and duration of bright sunshine.

The former is continuously monitored by Moll–Gorczynski pyranometers. These instruments are recalibrated every two years against the United Kingdom reference standard at the National Radiation Centre, Beaufort Park, Bracknell. The sensor is a thermopile in thermal contact with a copper plate across which a thermal gradient is created by the absorption of solar radiation by the optically black upper surface. The electromotive force developed by the thermopile is proportional to the irradiance and is automatically logged. Data were initially extracted manually from chart records but since the early 1960s the data have been recorded by MODLE Mk I equipment on computer-compatible tape (MODLE is an acronym for 'Meteorological Office Data Logging Equipment'). This device is shortly to be replaced by MODLE Mk III which will record on to magnetic tape in a cartridge. MODLE data are transcribed later to archive magnetic tapes.

Data concerning the duration of bright sunshine are added to the archive tapes after manual interpretation of Campbell–Stokes sunshine recorder cards.

Global solar radiation index (GSRI)

Within any given month, this was defined as the average global solar radiation ($\overline{G}$) measured over a one-hour interval for which there was a complete hour of bright sunshine, divided by the global solar radiation (G_0) that would have been measured outside the atmosphere over the same interval; it is thus a pure number.

The normalization factor G_0 was calculated from the solar elevation (a), the solar constant (I_0) (assumed invariant, and taken in this work to be 1353 W/m²), and the eccentricity of the earth's orbit. We may write

$$G_0 = I_0 \sin a\,(1 + 0.03345 \cos 2\pi\ \{\text{day}\ (n)/365\}),$$

where day (n) was the day-number of the day on which measurement was made (on 3 January, $n = 1$). The correction for the non-circularity of the earth's orbit gives results within 0·03 per cent of those quoted by Robinson (1966).

The GSRI could have been arrived at simply as the average of the normalized measurements of global solar radiation corresponding to 1·0 hour's bright sunshine in a given month, as recorded by a Campbell–Stokes sunshine recorder. A regression approach was used, however, so that values of radiation corresponding to less than one hour of bright sunshine could be used to improve the accuracy of the estimation.

When correlating hourly data, it is assumed that the normalized global radiation may be related to the fractional duration of bright sunshine, F_s, by the equation

$$G = \sum_{n=0}^{N} a_n\,(F_s)^n,$$

where a_n are coefficients.

In previous work (Day, 1961) the regression fit for $N = 1$ was used when correlating daily totals, but it was found that this linear relationship was not adequate for hourly data. The above equation was repeatedly applied to the data for $N = 1$ to $N = 5$, each solution of the coefficient values being that which gave the minimum sum of the squares of the data values about the polynomial. The improvement (decrease) in standard deviation of data about these regression equations, averaged for each calendar month of the 24 years, is shown in Figure 1. For each month there is substantial improvement up to the third-order regression, i.e. for $N = 3$, but thereafter the improvement is slight. This may be explained on physical grounds.

Figure 2 shows for a typical month the association between hourly values of normalized global solar radiation at the earth's surface and bright-sunshine duration during the hour (range 0–1 hour). It is clear that a linear relationship describes the relation well for bright-sunshine values over the greater part of the range. Departures from a linear fit are evident at the extremes of little or no sunshine during the hour and a mostly sunny hour. An explanation offered here is that if there is some bright sunshine in a given hour, the cloud cover is typically broken and not usually multi-layered; in the absence of bright sunshine the cloud cover is more likely to be multi-layered, with consequential increased scattering and attenuation of the incoming solar radiation. Stagg

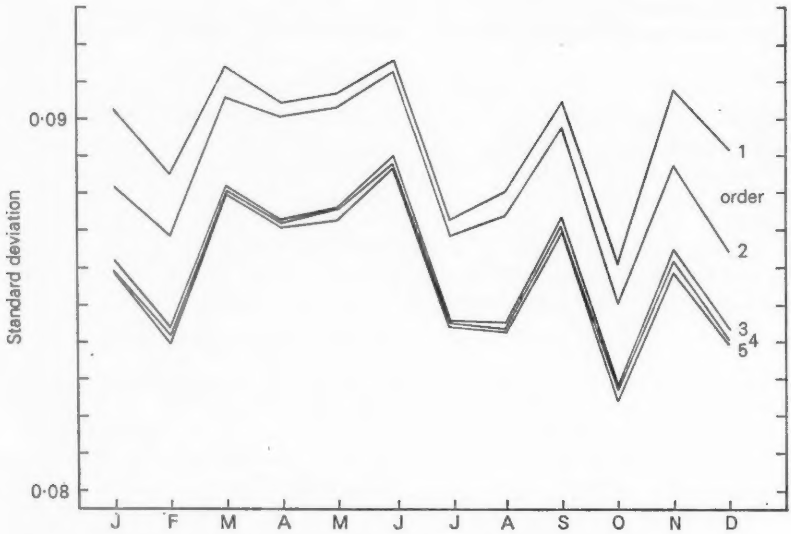

FIGURE 1—STANDARD DEVIATIONS OF NORMALIZED GLOBAL RADIATION ABOUT REGRESSION FITS OF ORDER 1 TO 5 BASED ON DATA FOR 1951–74

(1950) reported sunshine records to be systematically overestimated for periods of intermittent sunshine. As a consequence, in this situation, a particular radiation value is to be associated with too high an estimated (recorded) value of sunshine duration, as shown in Figure 3. Points A, B refer to recorded values and A′, B′ to true values. The effects of multi-layered cloud and systematic errors in reading from sunshine cards would combine to produce a quasi-cubic relationship between global solar radiation and the duration of bright sunshine.

Values of the GSRI for Kew for the period 1951–74, together with the standard deviations about the GSRI of the normalized global solar radiation values corresponding to 1·0 hour's bright sunshine, are given in Table I.

Reference was made to the reliability codes of the archived radiation values; only those quoted as being reliable were used.

In spite of these particular precautions it was still possible for poor or inadequate data to be included in the analysis. The seasonal accuracy of the standard deviation of the GSRI for each month is shown in Figure 4. Here the standard deviation is that of the data corresponding to a whole hour of bright sunshine about the GSRI (in Figure 1 the standard deviations are for all data about the regression solutions). The variation is largely explained by the number of hours of daylight in each month. Winter-month estimates of GSRI are also poorer because of the lower frequency of hours of 1·0 hour's bright-sunshine duration. The criterion was adopted that, if the standard deviation of the estimate for a given month exceeded 0·02, then the GSRI value was not used in further analysis. The assumptions here were that there had either been considerable instrumental difficulties or that there had been significant archiving errors.

LOW-PASS FILTERING TO INVESTIGATE THE SECULAR TREND IN 'GSRI'

A digital filter (a linear combination of unitary filters that were designed by Craddock (1968)) was used. It had the following characteristics:

(i) forty-one consecutive equally-spaced point values are required for each filtered value which is assigned to the 21st point in that sequence;
(ii) zero phase-change is introduced in those periodicities that are passed;
(iii) periodicities of <15 time-intervals are removed;
(iv) periodicities of >30 time-intervals are unattenuated.

When the filter is applied to the time-series of GSRI values, seasonal variations are removed but secular changes are retained. It was possible to secure a substantial reduction in the effect of periodicities of less than five years by applying a five-year running mean to the GSRIs for each calendar month through the analysis period before applying the compound unitary filter.

The transfer characteristics of the low-pass filter, both with and without the five-year running mean, are shown in Figure 5. The maximum amplitude of a sinusoidal signal

$$G = \sin(2\pi t/\tau)$$

over a 25-year period is plotted as a function of the periodicity τ.

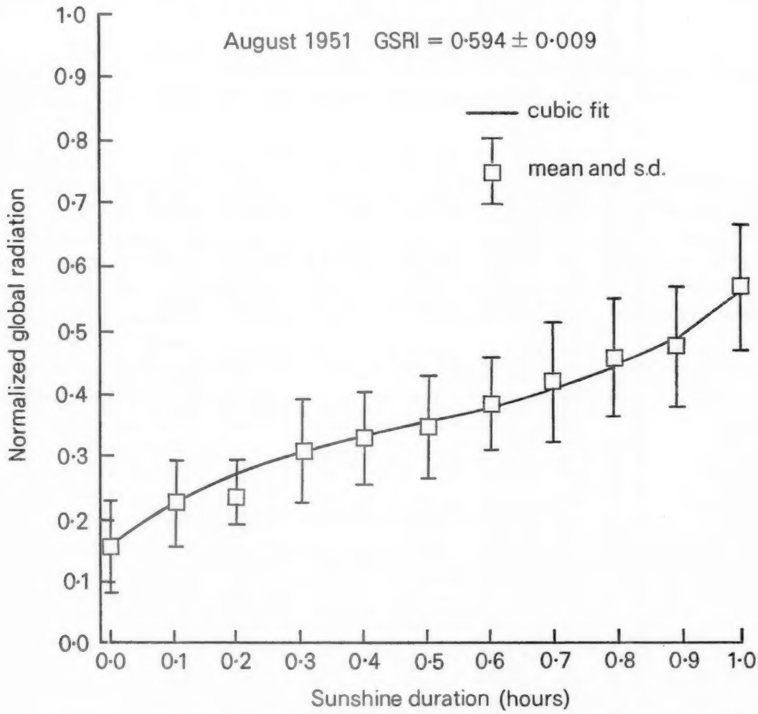

FIGURE 2—TYPICAL ASSOCIATION BETWEEN NORMALIZED GLOBAL RADIATION DATA AND SUNSHINE DURATION

The GSRI for August 1951 should read 0·574±0·009.

TABLE I—MONTHLY VALUES OF GLOBAL SOLAR RADIATION INDEX (GSRI) AND STANDARD DEVIATION (S.D.) OF NORMALIZED GLOBAL SOLAR RADIATION VALUES CORRESPONDING TO 1·0 HOUR'S BRIGHT SUNSHINE ABOUT THE GSRI

	JAN		FEB		MAR		APR		MAY		JUNE		JULY		AUG		SEPT		OCT		NOV		DEC	
	GSRI	S.D.	GSRI	S.D.	GSRI	S.D.	GSRI	S.D.	GSRI	S.D.	GSRI	S.D.	GSRI	S.D.	GSRI	S.D.	GSRI	S.D.	GSRI	S.D.	GSRI	S.D.	GSRI	S.D.
1951	0·511	0·022	0·566	0·021	0·601	0·016	0·585	0·008	0·609	0·011	0·618	0·008	0·594	0·008	0·574	0·009	0·559	0·012	0·504	0·011	0·448	0·017	0·454	0·015
1952	0·487	0·014	0·497	0·012	0·604	0·013	0·577	0·009	0·596	0·009	0·604	0·009	0·587	0·010	0·619	0·010	0·587	0·013	0·547	0·015	0·532	0·016	0·505	0·017
1953	0·445	0·018	0·536	0·016	0·496	0·011	0·578	0·010	0·635	0·008	0·602	0·009	0·677	0·012	0·613	0·009	0·618	0·010	0·561	0·014	0·528	0·015	0·494	0·018
1954	0·516	0·017	0·539	0·022	0·573	0·013	0·573	0·010	0·629	0·011	0·642	0·011	0·663	0·011	0·633	0·011	0·638	0·011	0·591	0·014	0·631	0·016	0·576	0·015
1955	0·508	0·021	0·596	0·017	0·569	0·010	0·643	0·008	0·651	0·008	0·631	0·010	0·617	0·007	0·595	0·007	0·595	0·010	0·583	0·012	0·463	0·022	0·516	0·019
1956	0·533	0·017	0·465	0·021	0·593	0·010	0·603	0·010	0·634	0·006	0·643	0·011	0·649	0·009	0·650	0·009	0·572	0·011	0·572	0·010	0·535	0·014	0·518	0·037
1957	0·483	0·016	0·543	0·011	0·581	0·011	0·596	0·008	0·634	0·007	0·609	0·006	0·584	0·011	0·597	0·009	0·612	0·017	0·550	0·013	0·527	0·013	0·470	0·019
1958	0·561	0·020	0·531	0·016	0·582	0·014	0·604	0·009	0·625	0·008	0·595	0·012	0·569	0·008	0·656	0·015	0·602	0·012	0·597	0·013	0·509	0·019	0·471	0·020
1959	0·448	0·013	0·512	0·013	0·574	0·012	0·567	0·010	0·622	0·008	0·635	0·007	0·603	0·007	0·605	0·007	0·571	0·006	0·571	0·007	0·533	0·020	0·520	0·020
1960	0·480	0·020	0·559	0·012	0·571	0·013	0·613	0·009	0·608	0·008	0·596	0·007	0·638	0·014	0·618	0·011	0·599	0·009	0·567	0·017	0·581	0·015	0·518	0·013
1961	0·492	0·018	0·566	0·012	0·628	0·008	0·605	0·013	0·617	0·007	0·628	0·007	0·617	0·008	0·632	0·009	0·610	0·011	0·596	0·010	0·589	0·014	0·509	0·014
1962	0·567	0·014	0·580	0·016	0·581	0·013	0·652	0·011	0·659	0·009	0·668	0·006	0·651	0·013	0·674	0·009	0·652	0·010	0·586	0·009	0·615	0·022	0·520	0·014
1963	0·525	0·022	0·550	0·013	0·624	0·011	0·656	0·010	0·646	0·008	0·653	0·007	0·617	0·008	0·599	0·011	0·628	0·009	0·610	0·010	0·557	0·018	0·465	0·016
1964	0·521	0·017	0·559	0·014	0·638	0·014	0·662	0·012	0·656	0·007	0·640	0·010	0·644	0·007	0·647	0·007	0·640	0·006	0·610	0·010	0·543	0·016	0·516	0·116
1965	0·520	0·018	0·604	0·029	0·656	0·010	0·641	0·016	0·694	0·011	0·708	0·010	0·666	0·012	0·641	0·009	0·656	0·011	0·581	0·008	0·577	0·011	0·554	0·013
1966	0·544	0·018	0·624	0·044	0·647	0·010	0·661	0·011	0·671	0·008	0·656	0·008	0·649	0·010	0·642	0·008	0·625	0·009	0·611	0·016	0·568	0·029	0.542	0·020
1967	0·549	0·026	0·601	0·012	0·644	0·009	0·634	0·013	0·629	0·010	0·658	0·008	0·635	0·007	0·643	0·008	0·617	0·012	0·646	0·010	0·525	0·015	0·549	0·020
1968	0·529	0·023	0·578	0·014	0·658	0·012	0·621	0·007	0·623	0·009	0·645	0·010	0·629	0·011	0·616	0·011	0·611	0·018	0·640	0·015	0·560	0·019	0·526	0·027
1969	0·593	0·023	0·646	0·016	0·611	0·012	0·635	0·007	0·635	0·010	0·633	0·012	0·646	0·007	0·628	0·010	0·642	0·011	0·601	0·009	0·599	0·014	0·541	0·027
1970	0·578	0·020	0·604	0·013	0·599	0·014	0·634	0·012	0·647	0·007	0·636	0·006	0·639	0·009	0·565	0·011	0·639	0·008	0·620	0·011	0·608	0·016	0·558	0·027
1971	0·560	0·024	0·597	0·016	0·635	0·013	0·640	0·010	0·630	0·007	0·671	0·010	0·630	0·006	0·613	0·010	0·619	0·007	0·639	0·007	0·593	0·009	0·593	0·025
1972	0·579	0·019	0·688	0·026	0·620	0·009	0·651	0·009	0·657	0·011	0·647	0·010	0·645	0·008	0·601	0·007	0·589	0·012	0·614	0·009	0·612	0·011	0·556	0·017
1973	0·610	0·021	0·611	0·013	0·614	0·011	0·647	0·011	0·666	0·010	0·661	0·006	0·646	0·009	0·617	0·007	0·623	0·010	0·628	0·013	0·596	0·012	0·582	0·016
1974	0·634	0·018	0·638	0·014	0·660	0·010	0·617	0·008	0·667	0·009	0·652	0·007	0·648	0·008	0·629	0·008	0·667	0·008	0·633	0·013	0·637	0·024	0·593	0·014

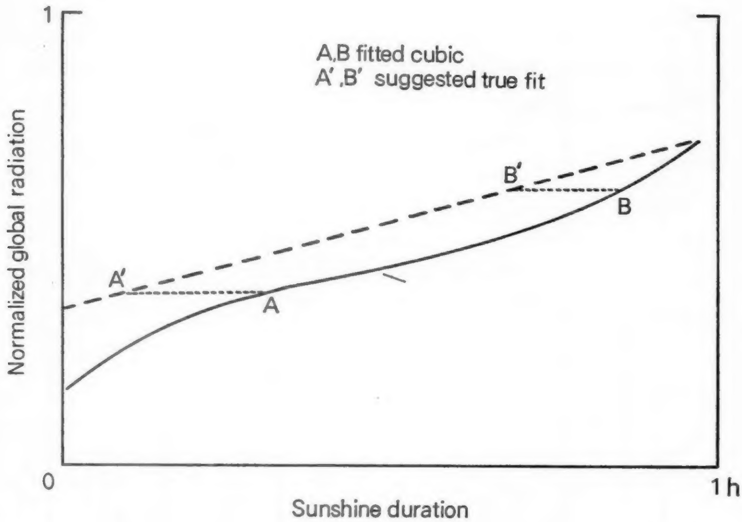

FIGURE 3—DEVIATION FROM LINEAR RELATIONSHIP BETWEEN NORMALIZED GLOBAL RADIATION AND SUNSHINE DURATION IN THE RANGE 0–1 HOUR

Both the unfiltered and the filtered time-series of GSRIs including and excluding the five-year running mean are shown in Figure 6. The low-pass digital filter has clearly been effective in removing the seasonal component in the GSRI time-series; the five-year running mean was needed to indicate long-term trends in GSRI because periodicities of about two years, which would otherwise be present in the filtered values, are not significant when considering trends over a period of 24 years.

The principal features of the trend as given by filtering the five-year running-mean values of GSRI are:

(i) a maximum in 1956,
falling rapidly to
(ii) a minimum in 1958,
followed by
(iii) a steady rise between 1959 and 1964, and
(iv) an approximately constant value from 1964 to the beginning of 1970.

(1970 marks the end of the period after truncation of the time-series resulting from the smoothing processes.)

Separation of seasonal and secular effects

It is seen from Figure 6 that the amplitude of the seasonal component of the basic GSRI time-series changed during the period considered. The change in seasonal pattern, as well as the secular trend, can be observed by constructing a GSRI diagram in which the individual monthly values are plotted orthogonally to the year-axis as in the coarsely contoured Figure 7. It can be seen

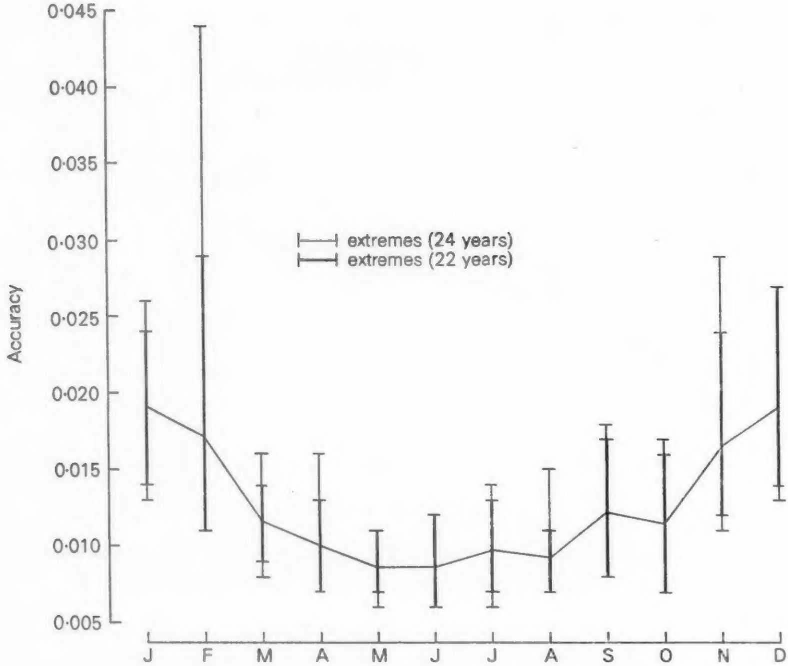

FIGURE 4—SEASONAL DEPENDENCE OF ACCURACY OF STANDARD DEVIATION OF 'GSRI' DATA ABOUT CUBIC SOLUTION

$$\text{Accuracy} = \frac{\text{Standard deviation of all data about cubic}}{(\text{Number of hours with 1.0 h bright sunshine})^{\frac{1}{2}}}$$

that, as the years progress, the 0·60 isopleth comes closer to the start and end of the year, corresponding to the improvement (increase) in winter-time values of GSRI.

Any section through the diagram parallel to the year-axis would indicate how the GSRI value for a particular month changed from 1951 to 1974.

It should be noted that values interpolated between the grid points do not have any significance.

Filtering the 'GSRI' diagram

It was useful to emphasize trends in both seasonal and secular patterns by applying a filter to the GSRI diagrams described above to remove 'high-frequency' components from the data field. This was achieved by fitting, by least-squares approximation, an eighth-order polynomial. The resulting smoothed field is shown in Figure 8. Phase changes may be introduced by this filter, but trends are shown clearly; the secular changes for January and July are shown in Figure 9.

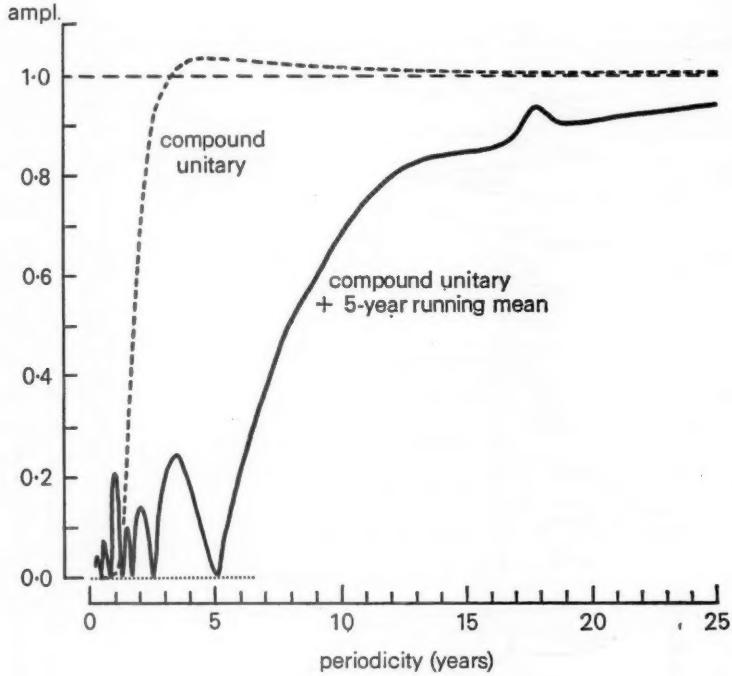

FIGURE 5—TRANSFER CHARACTERISTICS OF FILTERS

'ampl.' = amplitude of output for unit sinusoidal input.

Discussion

It is evident from Figure 9 that the winter-time value has changed over the period from 1951 to 1974 by about 25 per cent (from 0·46 in 1951 to 0·58 in 1974). Jenkins (1969) investigated the change in the duration of bright sunshine at London Weather Centre, Kew and Wisley, and his Figure 1 shows that since 1958 sunshine has increased by 17 per cent during the months from November to January, when compared with the long-term averages for the period 1931–60. He associated this increase with the Clean Air Act and its effect on both locally generated and advected atmospheric pollution. Lawrence (1969) showed that changes in smoke concentration at Kew were associated with surface winds from the direction of London (to the east) rather than from nearby buildings to the south-west. The change from the pre-sixties winter-time values to early-sixties values is about half that recorded over the total period from 1951 to 1974, that is to say about 13 per cent. This is of a similar order of magnitude to the finding of Jenkins.

The continued improvement in GSRI in the later sixties and to the present time may be associated with the change-over from solid fuel to oil and gas for domestic, commercial and industrial purposes, together with legislation limiting the emission of sulphur in London (1971). Auliciems and Burton (1973)

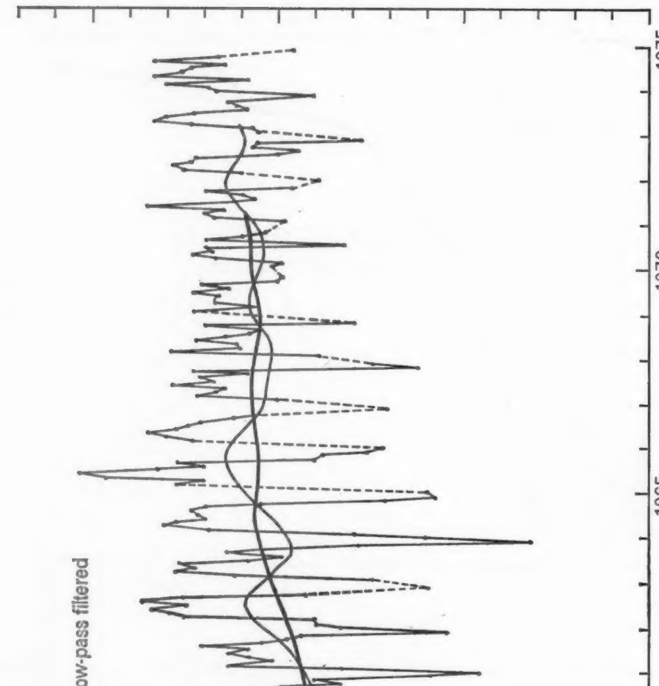

FIGURE 6—TIME-SERIES OF MONTHLY VALUES OF 'GSRI'
Dashed lines straddle doubtful monthly values.

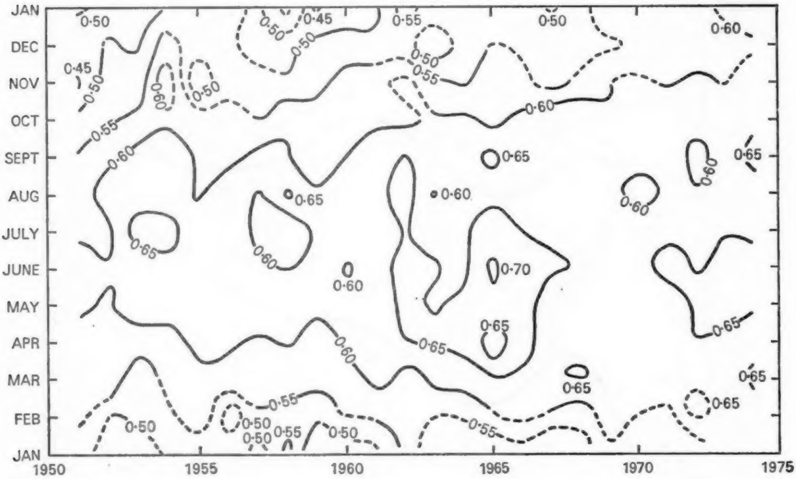

FIGURE 7—INTER- AND INTRA-ANNUAL VARIATION OF 'GSRI' VALUES

——— standard deviation of data <0·02
– – – standard deviation of data ⩾0·02

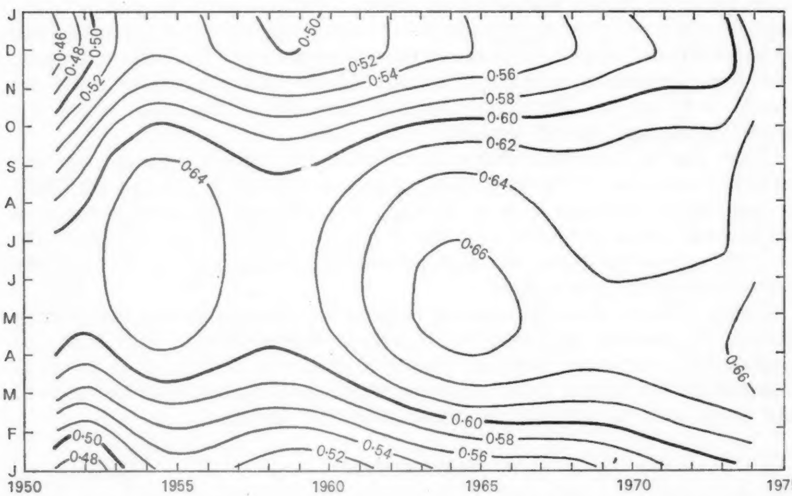

FIGURE 8—EIGHTH-ORDER POLYNOMIAL FITTING OF 'GSRI' DIAGRAM (FIGURE 7)

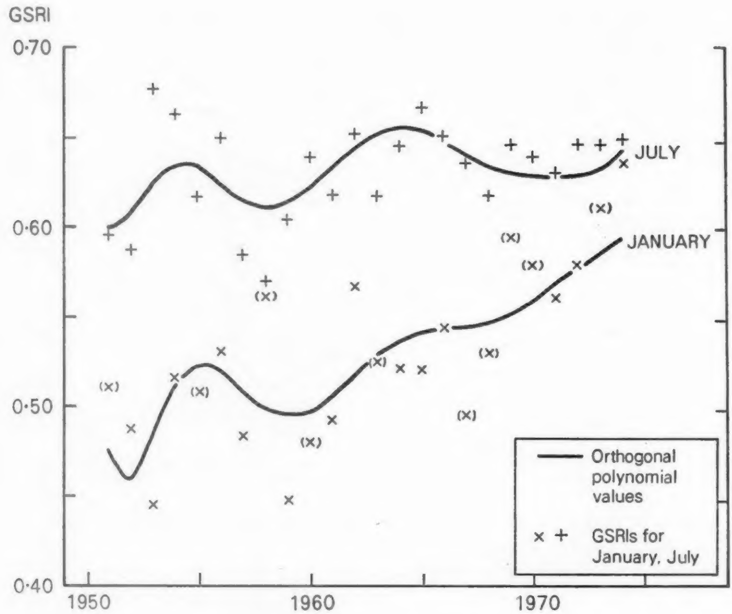

FIGURE 9—VARIATION OF 'GSRI' 1951–74

considered the smoke concentrations measured at Kew. Figure 10 shows the low-pass filtered time-series of smoke concentrations measured at Kew since 1926 plus the filtered time-series of GSRI for 1951–74. The present work supports their view that the reduction in smoke concentration is a consequence of technological improvements rather than of legislation. The scatter diagram and linear regression analysis of filtered GSRI values on smoke levels are shown in Figure 11. The correlation coefficient of −0.829 indicates that the former is strongly related, secularly, to the latter.

There was an 8 per cent change in GSRI in the summer between 1951 and 1964 but, as shown in Figure 7, this change was not monotonic and the GSRI is currently at the same level as in 1964. The difference in secular change in the summer when compared with the winter may be attributed largely to the change-over in fuel types, but the cause of the fluctuations in GSRI in the summer requires further study.

Figure 8 shows that the seasonal pattern has changed during the analysis period; the summer maximum has moved from June–July to May–June and a secondary maximum may be forming in August. Care must be taken in interpreting the filtered GSRI diagram; reference should always be made to the actual data to support identification of real features.

Conclusion

The seasonal and secular changes in global solar radiation under 'clear skies' have been shown to exist, and their magnitude has been calculated. It has

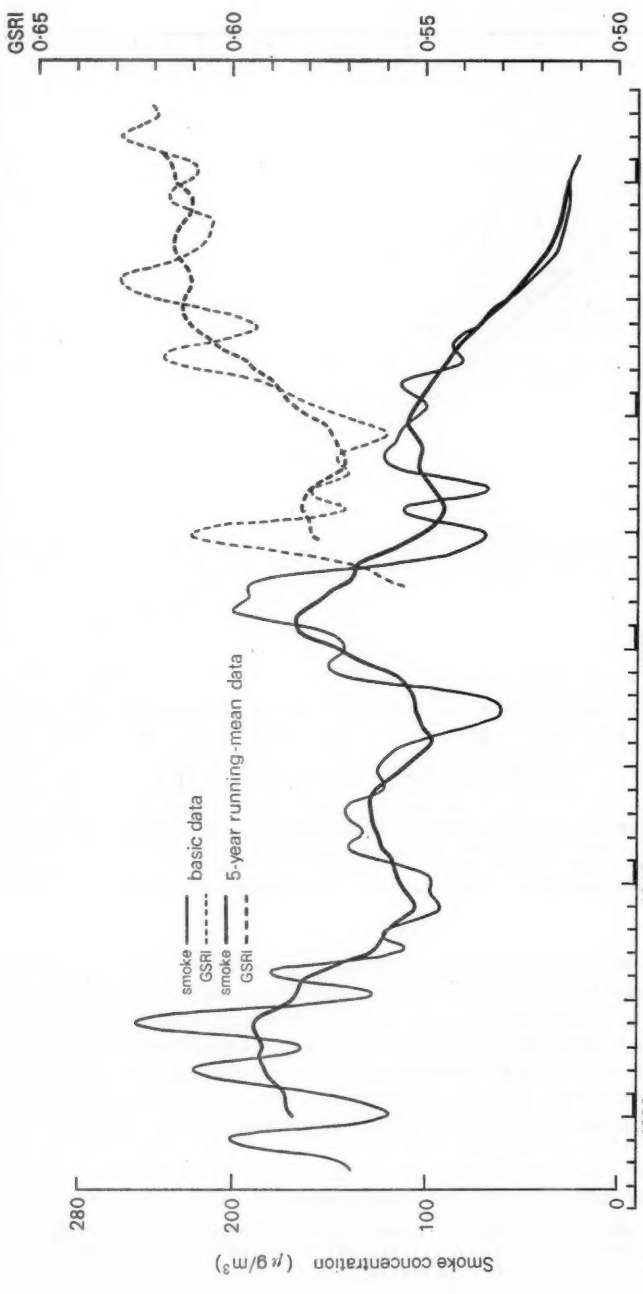

FIGURE 10—LOW-PASS FILTERED SMOKE CONCENTRATION (1926–73) AND 'GSRI' (1951–74) FOR KEW, USING FIVE-YEAR RUNNING-MEAN DATA AND BASIC DATA

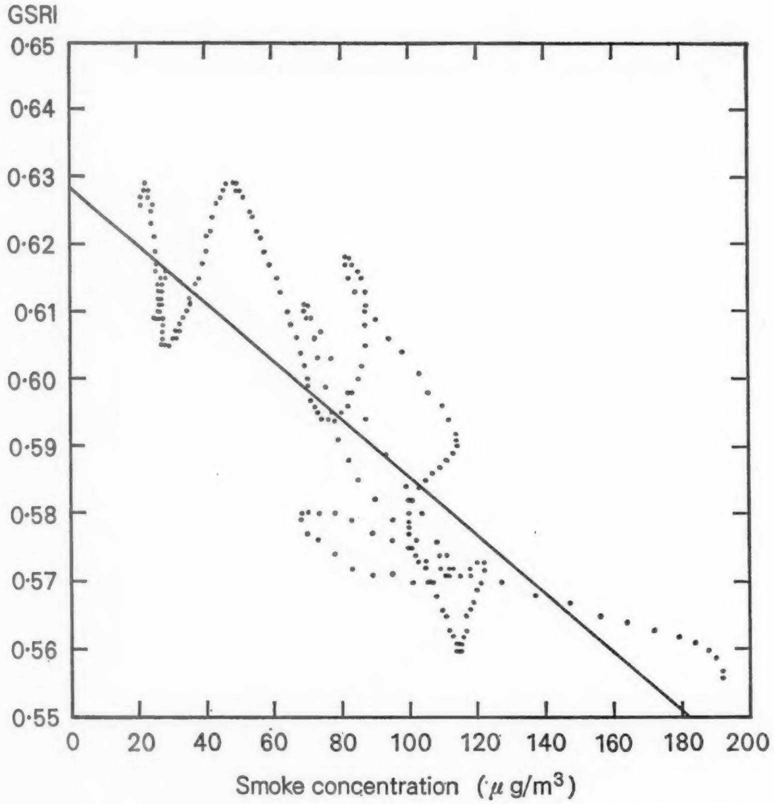

FIGURE 11—SCATTER DIAGRAM AND REGRESSION LINE OF 'GSRI' ON SMOKE CONCENTRATION

Correlation coefficient $R = -0{\cdot}829$; slope $= -0{\cdot}430$; constant $= 0{\cdot}629$.

been found that there has been a change of 8 per cent in the summer in the GSRI and a 25 per cent change in the winter. There was a variation of ± 4 per cent over the period of a decade in summer values. Changes in GSRI are largely associated with the reduction in artificial contamination of the atmosphere over Kew, a process that has continued throughout the 24 years, associated both with the change in fuel types as technology has developed and also with the laws brought in to control smoke and sulphur emission.

REFERENCES

AULICIEMS, A. and BURTON, I. 1973 Trends in smoke concentrations before and after the Clean Air Act of 1956. *Atmos Environ*, **7**, pp. 1063–1070.

BRAZELL, J. H. 1964 Frequency of dense and thick fog in central London as compared with frequency in outer London. *Met Mag*, **93**, pp. 129–135.
CRADDOCK, J. M. 1968 Statistics in the computer age. London, English Universities Press.
DAY, G. J. 1961 Distribution of total solar radiation on a horizontal surface over the British Isles and adjacent areas. *Met Mag*, **90**, pp. 269–284.
EVANS, D. C. 1957 A second report on fog at London Airport. *Met Mag*, **86**, pp. 333–339.
JENKINS, I. 1969 Decrease in the frequency of fog in central London. (Unpublished, copy available in Meteorological Office Library, Bracknell, Berks.)
LAWRENCE, E. N. 1969 High values of atmospheric pollution in summer at Kew and the associated weather. *Atmos Environ*, **3**, pp. 123–133 and 490–491.
ROBINSON, N. 1966 Solar radiation. Amsterdam, Elsevier.
STAGG, J. M. 1950 Solar radiation at Kew Observatory. *Geophys Mem*, **2**, No. 86.
WIGGETT, P. J. 1964 The year-to-year variation of the frequency of fog at London (Heathrow) Airport. *Met Mag*, **93**, pp. 305–308.

551.553.6:629.7.08

OPTIMUM AVERAGING TIME FOR REPORTS OF ALONG-RUNWAY AND ACROSS-RUNWAY WIND COMPONENTS TO AVIATION

By M. J. O. DUTTON

Summary

For selected occasions during a three-month winter period and a four-month summer period at London/Heathrow Airport winds averaged over intervals of time from 30 seconds to 10 minutes were compared with the 30-second means at later times, simulating the procedure whereby wind observations provided by Air Traffic Control are used by a pilot. A previous study looked only at the statistics of errors in the total vector wind. The results of this study of orthogonal components of the wind, along and across the runway direction, provided further confirmation that the ICAO-recommended 2-minute average wind adequately reduces the frequency of errors (in either component) of 10 knots or more, provided that the time lag between the supply of the wind report and its use is less than 5 minutes. The results for both components are broadly similar, although, for any given lag, errors of 10 knots or more in the across-runway component are on average about twice as frequent as those in the along-runway component.

Introduction

In two earlier studies, by Hardy (1974) and Dutton (1975), samples of turbulent wind conditions at Heathrow during summer 1973 and winter 1973–74 were analysed to determine what is the optimum averaging period to use for a wind report supplied to an aircraft pilot shortly before touchdown or take-off, for use as a forecast of the wind at touchdown or take-off. Both studies considered only the magnitude of the total *vector error* in the wind report and illustrated how the optimum averaging period not only varied with the lag between the supply of the report and its use, but was also dependent on the relative importance of errors of different magnitudes. Results showed that the root-mean-square (rms) error could normally be minimized by using an averaging period of 5–10 minutes but to reduce the frequency of errors in excess of a 10-knot or higher threshold a shorter averaging period was better; in general the shorter the lag and the higher the threshold, the shorter the averaging

period necessary to minimize the frequency of errors exceeding that threshold. The results suggested that the original provisional recommendation of the International Civil Aviation Organization (ICAO) (1967) for the use of a 2-minute average, a recommendation which they recently confirmed (ICAO, 1974), appeared to be a satisfactory compromise, at least for summer and winter in southern England.

In the study of winter turbulent cases the question was posed whether the results for *orthogonal components* of the vector errors, across and along the runway direction, for example, would be different; some evidence was presented to suggest tentatively that the optimum averaging period for reducing the frequency of error components in excess of 10 knots may be significantly shorter for the across-runway component. Errors in the longitudinal component are usually more critical since these can result in significant vertical deviations from the intended glide-slope on approach, causing a 'short' heavy landing, a 'long' landing or an overshoot. This report presents the results of a re-analysis of the combined wind data for summer 1973 and winter 1973–74, the longitudinal and lateral components of the vector error being considered separately.

The data

The basic data comprised series of 30-second wind averages recorded by the Meteorological Office Mk 5 wind system at Heathrow during the periods 3 May–7 August 1973 and 20 December 1973–25 March 1974. The methods of selection of suitable 'turbulent' periods for analysis were broadly similar for winter and summer samples (for example, mean wind speed 15 knots or more, cumulonimbus cloud present, passage of fronts/squalls); for details the reader is referred to Hardy (1974) and Dutton (1975).

The final summer sample totalled 79 hours (32 periods) and the winter sample 287 hours (47 periods).

Detailed information on runway usage during the selected periods was obviously necessary since wind components along and across the direction of the runway in use were required for this analysis; this information was obtained from Air Traffic Control arrival/departure records held by the Civil Aviation Authority.

Analysis

The object of the investigation was to compare, on a large number of occasions, the wind which might be supplied to the pilot with the wind which he would actually have encountered some minutes later at touchdown or take-off. The departure or error is defined as the magnitude of the difference between the forecast wind component (along- or across-runway) and the actual or encountered component that affected the aircraft at or near touchdown or take-off. The forecast or reported wind was taken as the observed wind averaged over a period of time varying from 30 seconds to 10 minutes (simple arithmetic averaging of the east–west and north–south components of the 30-second winds being used) and the actual wind was taken as the 30-second wind average some time (lag) later; this lag, which represented the interval between the wind observation and the aircraft touchdown or take-off, was also varied from 30 seconds to 10 minutes.

For all the 79 sample periods totalling 366 hours the across-runway and along-runway error components at every time-step, for 20 averaging periods and 20 lags, were evaluated and various statistics of these errors were computed.

Results and discussion

(a) *Root-mean-square errors*

Figure 1(a–b) shows the variation of rms errors as a function of averaging period for various lags from 30 seconds to 10 minutes. Although the variation is very similar for each of the two components, the optimum averaging time from the point of view of minimizing the rms error is consistently slightly shorter for the across-runway component. For lags of 2 minutes or more a 5- to 10-minute average appears to be the optimum for the along-runway component, while a 4- to 8-minute average is better for the across-runway component.

(b) *Percentages of errors exceeding given thresholds*

Figures 2 and 3 show the variation with averaging period, for various lags, of percentages of errors (out of a total of 40 802) exceeding 10 knots and 14 knots respectively.

(i) *10-kn threshold* (*Figure 2*)

For lags of 2 minutes or more a shorter optimum averaging period is indicated for the across-runway component; at shorter lags a 1- to 2-minute average is best for both components.

(ii) *14-kn threshold* (*Figure 3*)

Here a short averaging period is favoured for most lags for both components but again there is a tendency for the optimum averaging period to be shorter for the across-runway component. In addition the frequency of errors exceeding this threshold is a more sensitive function of averaging period for the across-runway component. In general the frequencies for the latter component are about double those for the along-runway component.

(iii) *Higher thresholds*

The results for higher thresholds show that, for both components, the higher the threshold the shorter the averaging period necessary to reduce the number of errors exceeding the threshold.

Table I lists percentage frequencies of errors within the selected sample exceeding thresholds of 6, 10, 14 and 20 kn for lags and averaging periods of 2, 5 and 10 minutes. Table II contains estimates for summer, winter and combined summer/winter, of the *true overall* frequencies of errors in excess of 10 kn for a lag of 5 minutes. The figures in brackets are the reciprocals of the true frequencies (rounded to the nearest hundred) and represent the average number of take-offs/landings in which one error of 10 kn or more is encountered. The figures for 'magnitude of total vector' are taken from the original analyses by Hardy (1974) and Dutton (1975). The estimation of the true overall frequencies is based firstly on Hardy's partly subjective assessment that, for the summer investigation, the overall frequency of errors of 10 kn or more would be about one-tenth of the frequency within the selected 79-hour sample, and secondly on the assumption that, for the winter cases, all errors of 10 kn or more within the quality-controlled recorded data (1775 hours) were included in the 287-hour sample, and that the 1775 hours of data could be considered unbiased from a meteorological point of view.

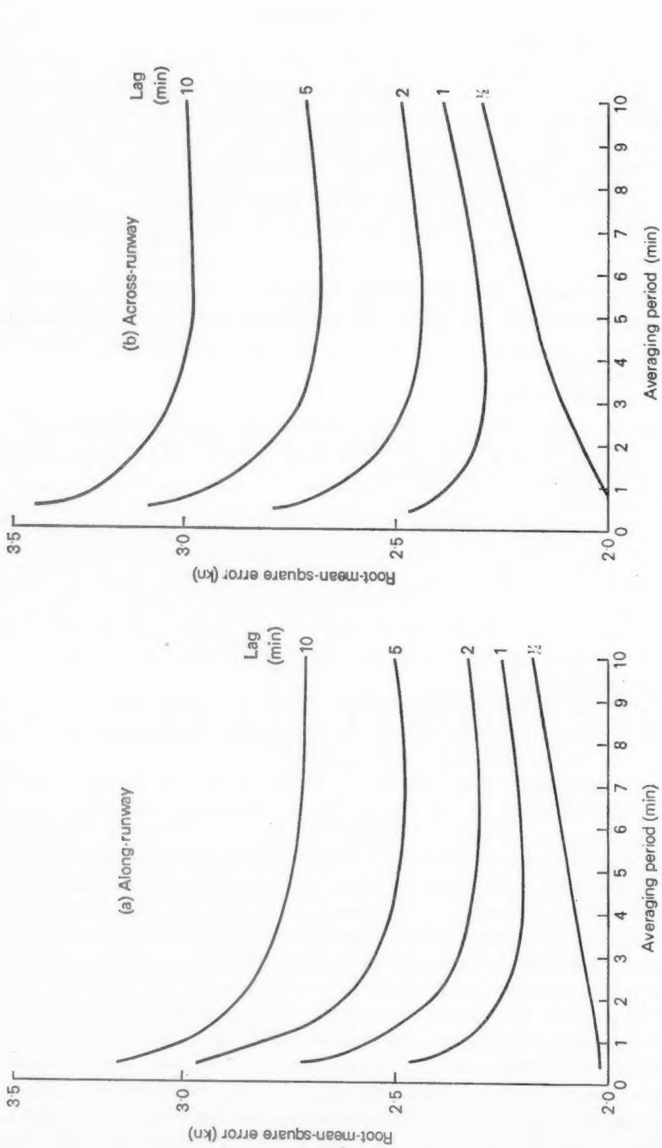

FIGURE 1—VARIATION OF ROOT-MEAN-SQUARE ERROR WITH LAG AND AVERAGING PERIOD (HEATHROW, SUMMER 1973 + WINTER 1973–74)

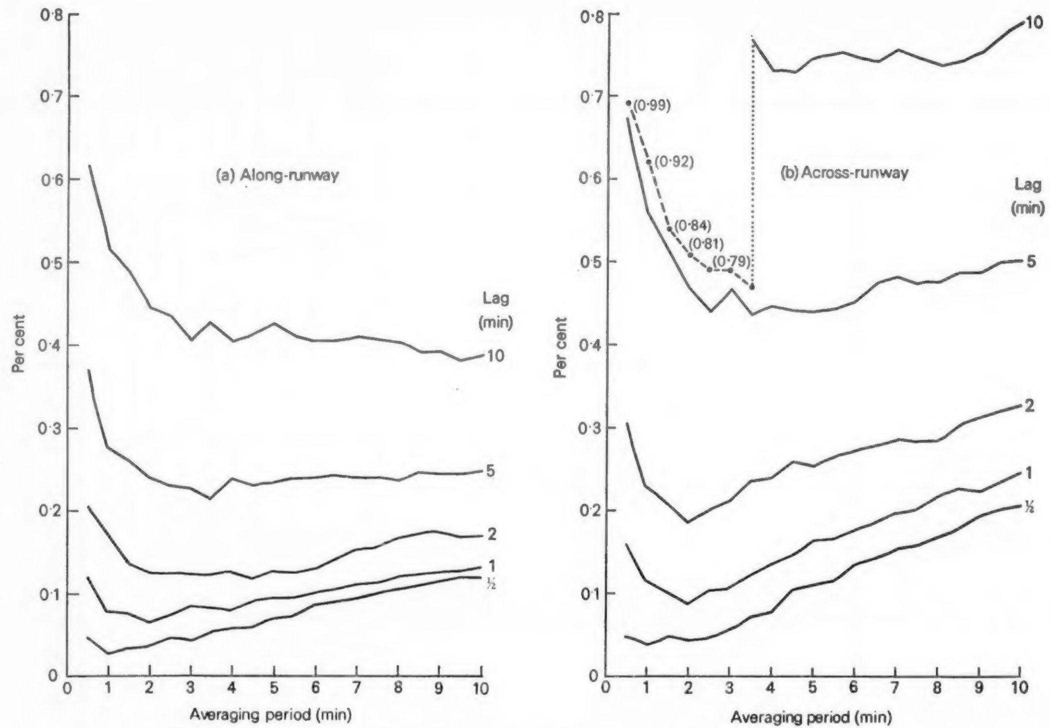

FIGURE 2—PERCENTAGE OF ERRORS $\geqslant$ 10 KNOTS—VARIATION WITH LAG AND AVERAGING PERIOD (HEATHROW, SUMMER 1973 + WINTER 1973–74)

The left-hand part of the topmost across-runway trace has been displaced by 0.3 per cent; bracketed figures denote actual values.

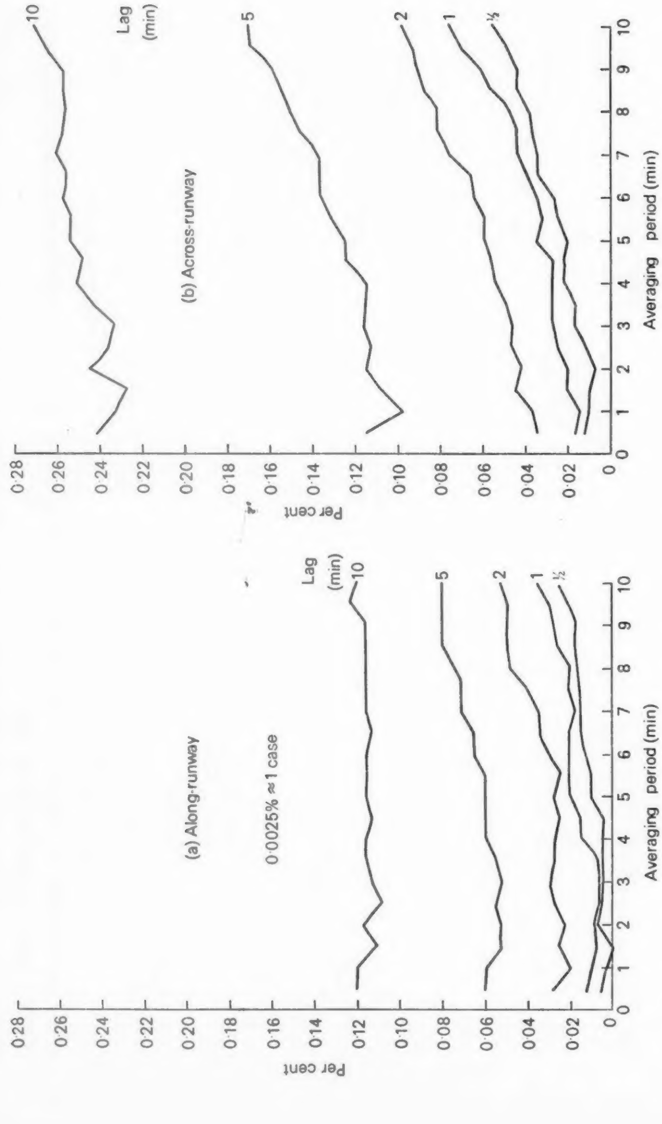

FIGURE 3—PERCENTAGE OF ERRORS ⩾ 14 KNOTS—VARIATION WITH LAG AND AVERAGING PERIOD (HEATHROW, SUMMER 1973 + WINTER 1973–74)

TABLE I—PERCENTAGE FREQUENCIES OF ERRORS EXCEEDING VARIOUS THRESHOLDS (SUMMER + WINTER)

		Along-runway component Threshold (kn)				Across-runway component Threshold (kn)			
Averaging period *min*	Lag *min*	6	10	14	20	6	10	14	20
2	2	2·25	0·128	0·022	0·0	2·63	0·184	0·042	0·007
	5	2·92	0·240	0·052	0·003	3·73	0·468	0·115	0·032
	10	4·19	0·444	0·118	0·017	5·22	0·811	0·245	0·071
5	2	1·71	0·128	0·027	0·0	2·16	0·253	0·059	0·017
	5	2·37	0·233	0·059	0·005	3·00	0·441	0·125	0·044
	10	3·59	0·424	0·115	0·025	4·42	0·745	0·253	0·081
10	2	1·76	0·169	0·052	0·005	2·31	0·324	0·098	0·020
	5	2·37	0·248	0·079	0·015	2·95	0·502	0·169	0·049
	10	3·37	0·387	0·120	0·027	4·38	0·787	0·270	0·098

(1 case ≈ 0·0025 per cent)

TABLE II—ESTIMATED TRUE PERCENTAGE FREQUENCIES OF ERRORS ⩾ 10 KNOTS FOR A LAG OF 5 MINUTES

	Averaging period *min*	Winter	Summer	Combined
Along-runway component	2	0·0291 (3400)	0·0439 (2300)	0·0365 (2700)
	5	0·0230 (4300)	0·0561 (1800)	0·0395 (2500)
	10	0·0239 (4200)	0·0610 (1600)	0·0424 (2400)
Across-runway component	2	0·0572 (1700)	0·0842 (1200)	0·0707 (1400)
	5	0·0511 (2000)	0·0866 (1200)	0·0688 (1500)
	10	0·0516 (1900)	0·1159 (900)	0·0837 (1200)
Magnitude of total vector	2	0·1230 (800)	0·1680 (600)	0·1455 (700)
	5	0·1070 (900)	0·1765 (600)	0·1417 (700)
	10	0·1025 (1000)	0·2090 (500)	0·1558 (600)

Figures in brackets are reciprocals of true frequencies (rounded to the nearest hundred) and represent the average number of take-offs/landings in which one error of 10 knots or more is encountered.

The 'combined' overall frequencies in Table II show that for the two seasons combined and with an averaging period of 2 minutes, errors in the more important along-runway component of 10 kn or more (about 1 in 2700) occur with about a half of the frequency of across-runway errors (about 1 in 1400) and about a quarter of the frequency of total vector errors (about 1 in 700) exceeding the same threshold. The differences in the statistics of large errors for the two components can be explained on the assumption that the large vector errors were frequently associated with appreciable (but less than 90-degree) wind-direction shifts. In turbulent wind conditions it is often the case that the aircraft lands or takes off roughly into the mean wind direction (with a headwind component); in this situation, if a sudden shift in wind direction occurs, the associated change in across-runway component will normally exceed the change in along-runway component.

Conclusion

The results of this study and others (Hardy, 1974 and Dutton, 1975) have shown that, for Heathrow (and similar terrain in southern England) the 2-minute averaging period, recommended by ICAO for this purpose, is particularly effective for reducing the frequency of errors exceeding a threshold of about 10 to 14 kn (10 kn for summer months, 14 kn for winter months), but that its use inevitably results in increased rms error and frequency of errors in the range 0–10 kn, which a 5- to 10-minute mean reduces more efficiently. The results have also illustrated well that, whatever the averaging period (within the ½- to 10-minute range), the use of as short a lag as possible is of paramount importance. During lengthy periods of strong winds when there are no large abrupt changes of mean wind speed and/or direction, conditions quite frequently experienced during the winter months, the use of a 5- to 10-minute average has proved markedly superior to that of a shorter-period average. On the other hand when there are frequent large variations in mean wind speed and/or direction such as those associated with the passage of major fronts (synoptic scale) or with convective activity including mesoscale squall lines, the use of a short averaging period of ½ minute to 3 minutes is favoured. These results apply both to along-runway and across-runway wind components and also to the vector-error magnitude.

In general it seems that the ICAO-recommended 2-minute average wind provides an adequate compromise, particularly when the lag between the supply of the wind report and its use is less than 5 minutes.

REFERENCES

DUTTON, M. J. O.	1975	Optimum averaging time of wind reports for aviation. *Met Mag*, **104**, pp. 231–243.
ELSE, C. V.	1974	The Meteorological Office Mk 5 wind system. *Met Mag*, **103**, pp. 130–140.
HARDY, R. N.	1974	A note on the optimum averaging time of wind reports for aviation. *Met Mag*, **103**, pp. 99–105.
MONTREAL, INTERNATIONAL CIVIL AVIATION ORGANIZATION	1967	Report of the 5th Air Navigation Conference, Montreal. Doc. 8720, AN-CONF/5, Montreal.
MONTREAL, INTERNATIONAL CIVIL AVIATION ORGANIZATION	1974	Report of the 8th Air Navigation Conference, Montreal. Doc. 9101, AN-CONF/8, Montreal.

551.508.952

INSTALLATION OF A DOBSON OZONE SPECTROPHOTOMETER IN THE SEYCHELLES

By J. H. CONVERY

Summary

A Dobson spectrophotometer was installed in November 1975 on the island of Mahé, Seychelles. The spectrophotometer is described and the pre-installation tests and operational routine are outlined.

Introduction

In the last five years there has been increased interest in the trend of total atmospheric ozone (O_3). This interest has largely arisen through fears that the amount of atmospheric ozone might be reduced by reactions involving exhaust products from the engines of supersonic transport aircraft (SST) and

chlorine produced by the action of solar ultraviolet on chlorofluoromethane (freon) compounds released from aerosol cans at the surface and diffusing upwards into the stratosphere. Discussion of these problems has been hampered by lack of information on the amount of ozone in the atmosphere and on the way in which it is changing. A recent statement by the World Meteorological Organization (1976) outlines the problems associated with the measurement of ozone and the interpretation of the results obtained.

Although satellite observations have greatly improved the spatial coverage of ozone measurements, they are limited to heights above 30 km and it is accepted that there is still a need for accurate values of total ozone measured from the ground. For 40 years the instrument for measuring total ozone, universally acknowledged as the standard by which all others are judged, has been the Dobson spectrophotometer. The geographical distribution of these instruments in equatorial regions at the beginning of 1975 is shown in Figure 1. Clearly, closure of the observing station at Gan early in 1976 has left a significant gap in the already thin equatorial coverage. As a means of filling this gap the Meteorological Office decided that, if possible, they should set up a new ozone observing station at Mahé, Seychelles. With the agreement of the Seychelles Directorate of Civil Aviation the station was opened at the new rawinsonde office at Mahé (4°40′ 36″S, 53°39′ 54″E) on 1 November 1975. As a further contribution to equatorial ozone measurement the Meteorological Office plans to open a second new observing station on the island of St Helena (15°56′ 18″S, 05°39′ 24″W) in October 1976.

PRINCIPLES OF OPERATION OF THE DOBSON SPECTROPHOTOMETER

The Dobson spectrophotometer is a double-beam monochromator operating in the ultraviolet Hartley absorption band of O_3 (290–340 nm).* It is shown schematically in Figure 2. Light from the sun or zenith sky enters through the window W and after deflexion passes through the narrow entrance slit S_1. From S_1 the light passes through a spectroscope (lens L_1, prism P_1 and mirror M_1) which forms a spectrum in the focal plane of the instrument where slits S_2 and S_3 are located. The position of the spectrum can be adjusted, by refraction through the quartz plate Q_1, so that light of the appropriate wavelength falls on slits S_2 and S_3.

The wavelengths chosen to pass through the slits S_2 and S_3, though separated by only about 20 nm, suffer strong differential absorption by the ozone in the atmospheric transmission path. The wavelengths used operationally are 305·5 nm with 325·4 nm, and 317·6 nm and 339·8 nm (described by Dobson as the *A* and *D* wavelength pairs respectively). The shorter, more strongly absorbed wavelength of each pair passes through S_2 and the longer, less strongly absorbed wavelengths through S_3. The instrument operates on the 'null' principle. The response of the detector to the light from S_2 and S_3 is balanced by attenuating the S_3 beam; the amount of attenuation required is measured and related to the total ozone in the optical path from the instrument to the top of the atmosphere. A sector disc SD, giving 78 alternations of light and dark per second, alternately passes light from S_2 and from S_3. After passage through a second matched spectroscope arrangement (L_2, P_2, M_2) and an interference filter, F, which serve to reduce unwanted background light, the radiation falls

* Historically the wavelengths have been designated in ångström units (1Å = 10^{-1} nm).

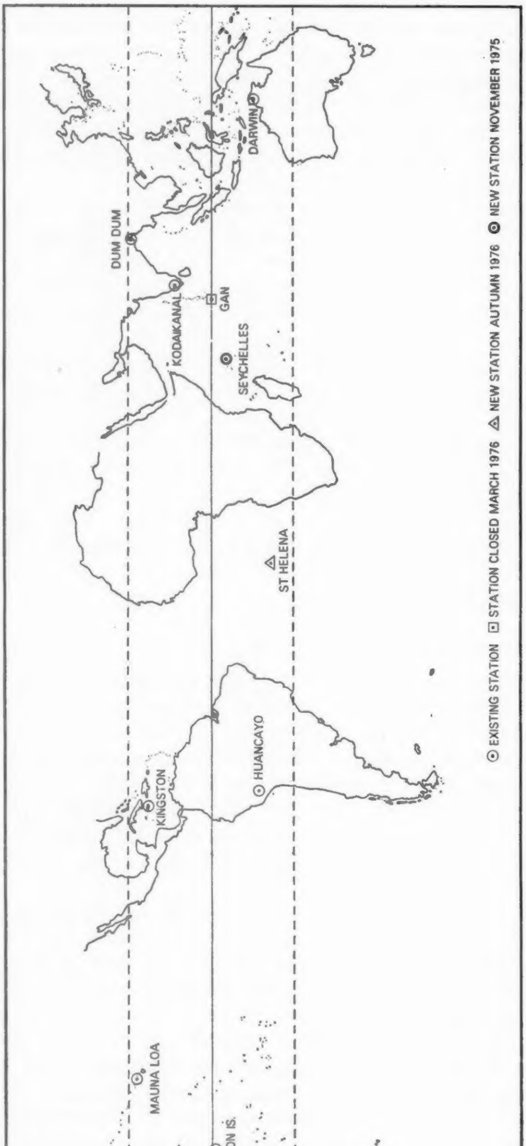

FIGURE 1—OZONE OBSERVING STATIONS (EQUATORIAL)

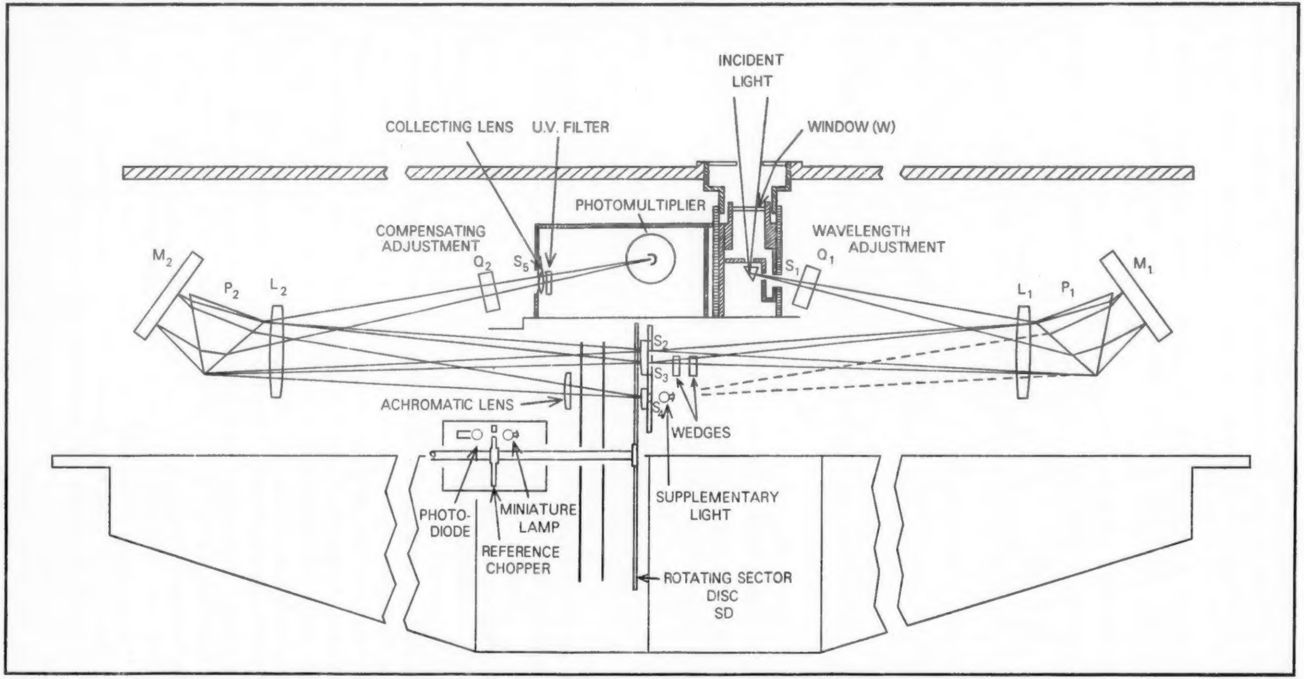

FIGURE 2—OPTICS OF THE DOBSON SPECTROPHOTOMETER
Based on Figure 3 in Dobson (1957). Slit S_4 is now only used for calibration purposes.

upon a photomultiplier cathode and any difference in response appears as an alternating voltage at the photomultiplier anode. This alternating signal is amplified and detected through a phase-sensitive detection system, the reference for which is derived from a small photodiode viewing a miniature light source through a slot in a rotating reference chopper mounted on the spindle of the sector disc SD. The signal appears ultimately as a current shown as an offset on a zero-centred microammeter. A full description of the electronics of the instrument has been given by Else *et alii* (1969).

The differential attenuation is measured by introducing into the optical path in front of S_3 an optical element (R) consisting of two pairs of quartz plates, each pair sandwiching a layer of a metallic deposit known as chromel. The sandwiches are graded in opposite directions and when introduced into the beam give a variation in transmission characteristic that is roughly wedge-shaped and the optical element is therefore referred to as an 'optical wedge'. The position of the wedge, and hence the degree of attenuation, is indicated by a graduated dial on the spectrophotometer casing; it is adjusted until the output current offset is reduced to zero. Clearly the dial reading at this wedge position is related to the total ozone measurement required. The spectrophotometer is described in detail by Dobson (1957).

The calibration of a Dobson spectrophotometer

The manufacturers of the Dobson spectrophotometer have found it impossible to produce wedges with identical optical characteristics, thus each instrument requires individual calibration. The relative opacity or gradient along the length of the wedge and an absolute value at some point on the wedge are required. In theory the determination of an absolute scale for the Dobson instrument should be possible at the observing station. If a series of observations are made on the sun as it rises to its zenith and if it is assumed that the total ozone has not changed during the observing period, then an absolute value for a point on the wedge can be deduced. In practice it has proved extremely difficult to obtain the very clear atmosphere required for such a calibration. The method used for absolute calibration is that one instrument, calibrated by observation on the sun at a high-altitude station in very clear air, is nominated as the international standard instrument. Substandard instruments are calibrated by a side-by-side comparison with the standard instrument through a range of sun heights. A very clear atmosphere is not essential for a side-by-side comparison, it being assumed that both instruments will suffer the same degree of interference from haze and dust. After an absolute comparison has been made, the drift in calibration of the wedge is monitored by the use of a standard lamp which produces a constant intensity of light.

The gradient of opacity of the wedge is determined by the use of a supplementary light source and a twin-lamp apparatus. The apparatus consists of a pair of balanced quartz–iodine lamps set above a split lens which can be located over the entrance window of the spectrophotometer. The supplementary light source is placed in front of S_4 (see Figure 2). S_2 is blanked off and light from the twin lamps, passing through the wedge and S_3, is balanced by adjustment of the wedge against the supplementary light. With the S_4 lamp at the same current, the twin lamps are then run individually and the new balance position of the wedge determined. The difference in the wedge positions for

the single and double lamps is a measure of the opacity which balances a doubling of lamp intensity. By adjusting the S_4 lamp intensity by small amounts and repeating the operation along the length of the wedge, a picture of the opacity of the wedge is built up.

The slit positions and optical alignment of the instrument are checked by using a mercury lamp and tuning on to particular spectral lines with Q_1 and Q_2.

The Seychelles spectrophotometer

Dobson Spectrophotometer No. 57 was manufactured in 1963 and after calibration by comparison with Dobson No. 1 at Oxford it was sent to the Commonwealth Scientific and Industrial Research Organization (CSIRO) at Canberra on an extended loan. From 1964 to 1973 it operated at Woomera and Perth, and on return to the United Kingdom was compared with the UK substandard, No. 41, at Bracknell. In the Antarctic summer of 1974–75 No. 57 was lent to the British Antarctic Survey to act as a travelling substandard. It visited the UK bases at Halley Bay, Argentine Islands and South Georgia.

On return to the United Kingdom it was decided to give No. 57 a thorough overhaul and to modernize the electronics. The RCA 1P28 photomultiplier was replaced by an EMI 9781A with a consequent increase in sensitivity by a factor of over 200. A transistorized system of amplification (Else *et alii*, 1969) replaced the original circuits designed 40 years ago. The modernization produced only a marginal improvement in the signal to noise ratio but electronics faults can now be rectified more simply by the replacement of a printed-circuit board.

Calibration of the Seychelles spectrophotometer

Before the instrument left Bracknell the Q-lever positions were calibrated by using spectral lamps. The lamps provide six wavelengths over the 34·3-nm range in which the Dobson is operated and the operational wavelengths can be set to within 0·05 nm. The gradient of the wedge was calibrated over 260° of dial at 2° intervals. The absolute calibration was determined by comparing Dobson No. 57 with No. 41, the UK substandard instrument. Dobson No. 41 was itself compared with the accepted World Meteorological Organization standard instrument, from Boulder, Colorado, at Belsk, Poland, in June 1974 (Losiowa, 1975).

Dobson No. 57 was air-freighted to the Seychelles in a custom-built box. Upon arrival the instrument was given three days to acclimatize while the facilities and calibration equipment were inspected. Mercury-lamp and standard-lamp tests were then carried out. Table I shows the Q_1 setting correction (ΔQ). ΔQ is the difference between the angular position of Q_1 determined by the mercury-lamp test on site (mean Q_1) and the angular position of Q_1 defined by the original mercury-lamp test at Bracknell (calibrated Q_1). The corrections

TABLE I—MERCURY-LAMP TESTS ON DOBSON NO. 57

Location	Date	Instrument temp.	Calibrated Q_1 setting	Mean Q_1	ΔQ
Bracknell	16.10.75	15·9°C	84·29	84·39	+0·10
Mahé	29.10.75	29·0°C	85·63	85·45	—0·18
Mahé	3.11.75	30·0°C	85·74	85·64	—0·10
Mahé	7.11.75	29·1°C	85·64	85·50	—0·14

ΔQ is measured in angular degrees.

found were within the limits of experimental error. The standard-lamp tests showed a change between the values obtained in the Seychelles and the pre-dispatch tests carried out at Bracknell. This change indicated that during transit there had been a small shift in the position of the optical wedge on its carriage. The relationship between the dial value and total ozone is complicated (Dobson, 1957) and will not be discussed in this paper. The change in standard-lamp values corresponded with a −0·6 per cent change in total ozone. A +0·6 per cent correction will be applied to all data from this instrument to accommodate this shift. The gradient of the wedge was checked by repeating the twin-lamp tests undertaken at Bracknell. The gradient observed was identical to that observed at Bracknell.

Routine observations in the Seychelles

The spectrophotometer is housed in a room attached to the balloon shed on the rawinsonde site which is situated on the north side of South Island. The main runway of the new airport now joins South Island to Mahé, the largest island in the Seychelles. The area round the site is dusty owing to the immediate proximity of two quarries and the airport perimeter road, which has a top surface of crushed coral. The ozone observations will be made at about 0830 local time, and it is hoped that this will be before quarry blasting has begun.

The ozone observations are made on a flat concrete circle situated some 20 metres clear of the building. Observations are made daily on the *A* and *D* wavelengths. It is hoped that the majority of observations will be made on the direct sun. Observations can be made on the zenith sky, clear or cloudy, but Thomas *et alii* (1974) estimate an increase in scatter of 2·7 per cent compared with direct-sun observations.

Once a month a mercury-lamp test and a standard-lamp test are carried out and the resulting data together with the daily observations are sent to Bracknell for computation. From Bracknell the computed daily ozone values are sent to the World Ozone Data Centre at Toronto in Canada.

Daily observations began at the Seychelles station on 1 November 1975. The quality of a Dobson observation depends very much on the care exercised in making the observation and the condition of the spectrophotometer, but with trained observers and a well-calibrated instrument, an error of less than ±2 per cent in total ozone should be possible. A four-month overlap of observations was achieved between the opening of the Seychelles station and the closure of the one on Gan on 1 March 1976. The total ozone values for the two stations are illustrated in Figure 3. The total ozone amounts are shown in Dobson Units (milli-atmo-centimetres).

Acknowledgements

I would like to thank Mr M. J. Longworth and Mr C. Brookes for their invaluable assistance in setting up Dobson No. 57 in the Seychelles. I would also like to thank Dr R. E. W. Pettifer for his guidance and advice.

References

DOBSON, G. M. B. 1957 Observers' handbook for the ozone spectrophotometer. *Ann Int Geophys Yr, London*, **5**, Part II, pp. 46–114.

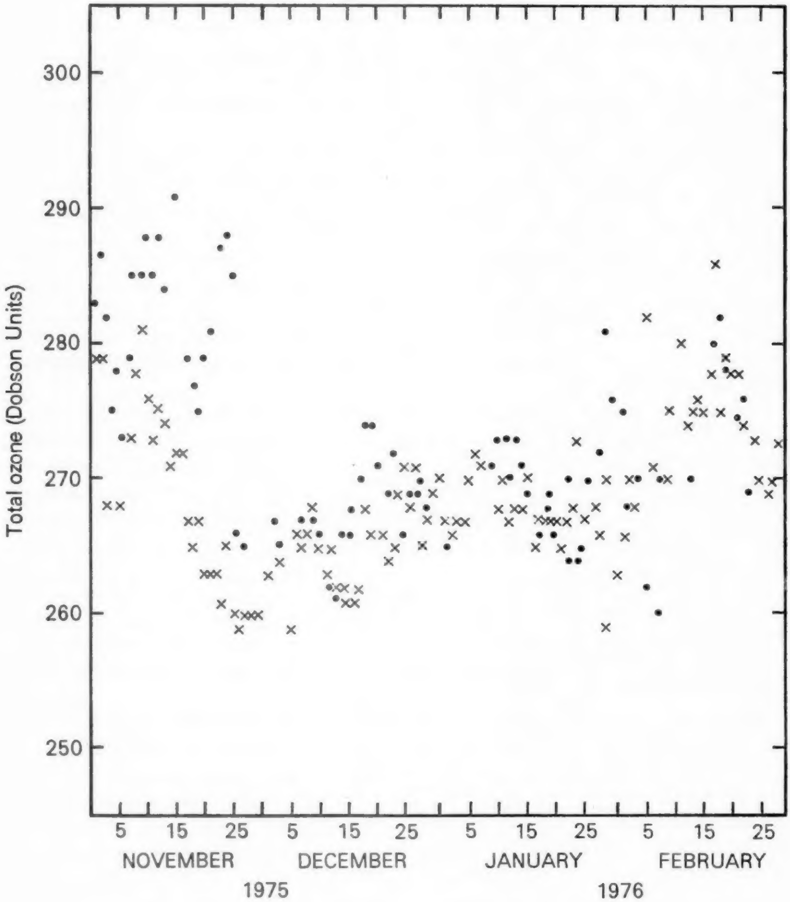

FIGURE 3—DAILY TOTAL OZONE AMOUNTS RECORDED AT GAN AND SEYCHELLES DURING A FOUR-MONTH OVERLAP PERIOD

× Gan ● Seychelles

ELSE, C. V., POWELL, D. B. B., and SIMMONS, E. L. 1969 An improved solid state amplifier for the Dobson Ozone Spectrophotometer. *Ann Géophys*, **25**, pp. 313–315.

GENEVA, WORLD METEOROLOGICAL ORGANIZATION 1976 *WMO Bulletin*, **25**, pp. 59–63.

LOSIOWA, A. 1975 The international comparison of ozone spectrophotometers, Belsk, 24 June–6 July 1974. *Publications of the Institute of Geophysics, Polish Academy of Sciences*, pp. 3–59.

THOMAS, R. W., GUARD, K., HOLLAND, A. C., and SPURLING, J. F. 1974 Ozone measurement systems improvements studies. *NASA Tech Note* D-7758, p. 73.

REVIEWS

Cloud physics and weather modification, by Yu. S. Sedunov. 240 mm × 170 m, pp. iv + 106, *illus.* (translated from the Russian by Israel Program for Scientific Translations, Jerusalem), John Wiley and Sons Ltd, Baffins Lane, Chichester, Sussex, 1974. Price: £6·75.

This book is a translation of a collection of five papers published in 1970 in the USSR. The first of these is a report by the editor of the weather-modification program in the USA. It represents the findings of a Soviet delegation who visited several American university and government agencies engaged in cloud-physics and weather-modification research during the autumn of 1969. The report is mainly factual, although there are some generalized value judgements. No comparisons with similar research efforts in the USSR are offered. The article is interesting in providing a limited Soviet view of some United States research in the late sixties but it is likely to be of greater value to the historian than the scientist today.

The second article is entitled 'Modifications of clouds and precipitation in central European USSR' and is written by I. V. Litvinov. The title is rather ambiguous as the author attempts to predict an upper limit to precipitation amounts which might be obtained by cloud seeding in a particular region of the Soviet Union. There is no discussion of the physics of the seeding process and the assumptions made are so gross and arbitrary that it is difficult to see any value in the paper.

The third contribution, by E. L. Aleksandrov, is a survey of methods of measuring concentrations of cloud-condensation nuclei in the 'Aitken' region. The author categorizes instruments by the methods used to generate a super-saturation. There are sections on expansion chambers and also on thermal and chemical diffusion chambers.

The fourth paper is a review of the micro-physics of droplet coagulation by V. M. Voloshchuk. The concept of collision efficiency is developed in the contexts of droplet growth through coalescence and of the washout of small aerosol particles by cloud droplets. The approach is primarily theoretical.

The final article is by S. P. Belyaev. He extols the use of flash illumination and photography in aerosol research. In particular he considers the usefulness of the technique in the investigation of deposition and bouncing of particles on solid objects and into aspirated pipes, and in the study of concentration fluctuations and of droplet coalescence.

Apart from the fact that all of these papers are very dated, their choice for translation and publication in book form, under the title of 'Cloud physics and weather modification' is particularly inappropriate. Whatever scientific merit the two weather-modification papers may have had, it can only have been realized in front of a Soviet audience. This also applies to the third paper because the major advances in the field, at least up to the time of this report, have been made outside the USSR and are already well documented in the English literature. Neither of the remaining papers can be said to be a key contribution even in its own specialized area within cloud physics. This is all particularly disappointing, when, as at present, a detailed account of the physical principles and methodology underlying the claimed success of Soviet cloud and weather modification is so urgently required.

P. RYDER

Climate and the environment—the atmospheric impact of man, by John F. Griffiths. 215 mm × 135 mm, pp. 148, *illus.*, Paul Elek Ltd, 54–58 Caledonian Road, London N2 9RN, 1976. Price: £2·95.

This book is one of the first three publications in a new Environmental Studies series, and seems to be aimed at the pre-university or undergraduate non-scientist. Since so many books have appeared in recent years covering the general descriptive aspects of climatology (with or without applications), a newcomer to the lists would need to achieve considerable originality of approach and presentation in order to stand out. As indicated by the sub-title, the book's main theme is the consideration of man's reaction to his climatic conditions, and this is an estimable peg on which to hang a description of climate. However, parts of the book show signs of having been compiled much too hastily and explanations of meteorological phenomena are often oversimplified and do not follow logically from the evidence presented.

The first half of the book, devoted to the description of the basic climatic factors, is the more unsatisfactory in this respect. Most of the diagrams are taken from published sources and effort has not been made in all cases to ensure consistency between diagram, legend and text. Some diagrams contribute little to the general theme and appear to have been included as 'makeweights'. The largest chapter in the first half deals well with 'Radiation and the Energy Budget', but the details presented here (including the astronomical and heat-budget equations) do not match the simple descriptive tone of the other chapters. The chapter entitled 'Climatic Patterns' is a curious collection of material on typical seasonal temperature variations, definitions of humidity measures, an introduction to climatic classification, a discussion of temperature fluctuations on time-scales of seconds and 10^5 years and, finally, a presentation of the world's maximum rainfalls versus duration (with, incidentally, the enveloping curve's equation in different units on the diagram and in the text).

The second half of the book is concerned with applications of climatology, and here again there is inconsistency of presentation between the section on Human Biometeorology, which gives lots of rather complex equations and diagrams, and the other chapters where simple descriptions suffice. The 'Climate and Building' chapter is a good straightforward analysis of the importance of a knowledge of climate to those involved in the planning and designing of habitable structures. Those who have experienced the rigours of working in offices not capable of withstanding the vagaries of the local climate may derive a certain grim amusement from the following quotation in the section on primitive architecture:

> 'The worst the modern architect faces is a dissatisfied client; when the primitive architect errs, he faces a harsh and unforgiving Nature.'

The remaining chapters on agriculture, atmospheric modification, city climates and miscellaneous applications of climatology are well constructed and readable. The second half of the book can thus be recommended as a non-technical description of some of the applications of climatology which are important to man's well-being, but the basic climatological ground-work in the first half of the book is not well planned or executed.

J. S. HOPKINS

NOTES AND NEWS

Post Office 'Viewdata service'

The Meteorological Office has agreed to take part in a trial of the Post Office's 'Viewdata service'. 'Viewdata' uses existing telephone lines to connect a Post Office data bank with the subscriber's television set and makes it possible for information to be called up on demand. The adaptation of the television set is similar to that needed for reception of the experimental BBC 'Ceefax' and IBA 'Oracle' transmissions. As at present envisaged, 'Viewdata' may prove to be a means of providing specialized meteorological services for groups such as climbers and walkers, yachtsmen, farmers and others which will cover all costs.

Symbol for specification of temperature difference or interval

Until about 1961 the elevated degree symbol ° was used indifferently to indicate both spot values and ranges, differences, depressions, increases, decreases, errors, tolerances etc. of temperatures on the Centigrade and Fahrenheit scales. In 1962 the Comité International des Poids et Mesures (CIPM) approved the use of the degree Kelvin with symbol °K to indicate the unit both for a difference between two thermodynamic temperatures and for a thermodynamic temperature itself. This decision rendered the form °A obsolete. The CIPM decided at the same time, that, if judged necessary, the international symbol 'deg' could be be used for the indication of an interval or difference of temperature. Since the Fahrenheit scale was not then totally obsolete the *Meteorological Magazine* started to use the form 'degC' to indicate temperature intervals on what is now properly called the Celsius scale. At its 13th meeting in 1967 the Conférence Générale des Poids et Mesures (CGPM) decided that the unit of thermodynamic temperature should be denoted by the name 'kelvin' and that its symbol should be 'K'. The CGPM also stated that temperature intervals might also be expressed in degrees Celsius, and that the decisions taken by the CIPM in 1962, including the use of 'deg' were abrogated but that usages which derived from these decisions remained permissible for the time being. British Standard BS5555:1976* recommends 'K' to denote a temperature interval but also permits the use of '°C'. In conformity with this recommendation the *Meteorological Magazine* will in future normally use 'K' to denote a temperature interval unless special circumstances require the use of '°C', and the obsolescent form 'deg' will be discontinued. It should be noted that the unit 'kelvin' in common with other units named after individuals such as 'henry', 'newton', 'pascal' and 'watt' is not spelt with an initial capital letter, despite the use of a capital for the symbol 'K'.

---

*London, British Standards Institution, 1976: SI units and recommendations for the use of their multiples and of certain other units. BS5555:1976.

OBITUARIES

It is with regret that we have to record the death on 21 July 1976 of Mr H. W. Jones, Assistant Scientific Officer, of Manchester Airport, and on 23 July 1976 of Mr T. Ross, Second Engineer, Ocean Weather Ship Base, Greenock.

THE METEOROLOGICAL MAGAZINE

VOL. 105 NO. 1252 NOVEMBER 1976

CONTENTS

NOTICES

It is requested that all books for review and communications for the Editor be addressed to the Director-General, Meteorological Office, London Road, Bracknell, Berkshire, RG12 2SZ, and marked 'For Meteorological Magazine'.

The responsibility for facts and opinions expressed in the signed articles and letters published in this magainze rests with their respective authors.

Complete volumes of 'Metorological Magazine' beginning with Volume 54 are now available in microfilm form from University Microfilms Ltd, St Johns Road, Tylers Green, High Wycombe, Buckinghamshire, England.

Full size reprints of out-of-print issues are obtainable from Johnson Reprint Co. Ltd, 24–28 Oval Road, NW1 7DX, London, England.

Issues in Microfiche starting with Volume 58 may be obtained from Johnson Associates Inc., P.O. Box 1017, Greenwich, Conn. 06830, U.S.A.

Printed in England by Heffers Printers Ltd, Cambridge
and published by
HER MAJESTY'S STATIONERY OFFICE

60p monthly **Annual subscription £8.28 including postage**

Dd. 290748 K16 11/76 ISBN 0 11 724377 9